Learning musical contour on a tabletop

Conference or Workshop Item

Learning Musical Contour on a Tabletop

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ABSTRACT

Many successful tabletop applications for music making have been developed, and the technology has been investigated from different perspectives. Yet, to date, despite optimistic claims regarding their potential as learning tools, their role in helping people to explore, acquire, and reason about musical concepts has been sparsely researched. We have developed an exploratory study around a simple tabletop application that allows people to make music using a visual representation of melodic contour. Our aim is to understand whether and how such system might help people to reason about music in terms of contour while at the same time affording an enjoyable music making experience to musically untrained people. Our findings suggest that the system has potential as a learning tool, especially for beginners, but tutoring is still necessary to acquire, use, and express concepts precisely.

1. INTRODUCTION

The aim of this exploratory study was to understand in what ways, if any, digital tabletop musical instruments (DTMIs) could help people to understand the concept of *contour*, and use it to create, and reason about, melody. Contour is a visual metaphor that is applied to melody, often described as the way in which pitch rises and falls along a melody [1, 2], and sometimes referred to as the melody's *shape*.

This study used a DTMI specifically designed to emphasise the relationship between contour and visual shapes, with the intention that participants would be able to make this association while using the system, and therefore to acquire the notion of contour, so that they could then confidently compose or analyse melodies using the kinds of visual metaphors traditionally used by musicians. However, the study was also part of an effort to explore the role of musical tabletops in the broader context of music appreciation, a topic that has been sparsely investigated, despite the fact that musical applications are among the most popular applications developed on digital interactive tabletops.

2. BACKGROUND

Although interactive tabletops are increasingly gaining attention as educational tools, in-depth empirical research into them is still sparse at best [3]. As often happens with novel technology, interactive tabletops have been overcharged with expectations and optimism; therefore it has been suggested that their potential should be systematically researched [4].

Interactive tabletops are often seen as collaborative platforms, and a wide range of applications and studies have been developed around this technology – e.g. group work [5, 6], collaborative learning [7, 8], fostering creativity [9], and so on. Among others, music making is one of the most successful and widely explored applications, with studies proving the value of platforms such as the Reactable [10] and the Audiopad [11] as collaborative music making platforms [12].

The exploratory study [13] presented here aims to be a first step toward a systematic approach to understanding the role of DTMIs as tools for discovering and reasoning about musical concepts, and for music making.

3. PURPOSE OF THE STUDY

Our hypothesis was that a musical instrument with an interface specifically designed to convey certain concepts visually, that requires no musical training, and that provides an enjoyable music making experience, would allow people to acquire the basic and fundamental musical concept of contour, useful in facilitating activities such as music appreciation, or even instrument studies and composition. It is therefore necessary to frame the study in a way that relates visual and musical ideas. We can phrase the hypothesis in more detail as follows:

1. a DTMI that offers a visual representation of music and allows participants to manipulate it with a gestural interface will give participants tools to understand melodies in terms of contour;

2. a playful interface based on a simplified visual representation of music will allow participants to approach a music composition task without causing undue stress and encouraging concentration and enjoyment.

4. STUDY DESIGN

4.1 Conditions

Two variables were manipulated in this study.

IV1: **Explanation of Contour.** In order to determine whether the use of the tabletop interface alone can help people acquire the concept of contour, two groups

of participants were formed: the first group was given an explanation of contour, making explicit references to the vocabulary of contour, and to the connection between the visual metaphors and the corresponding sounds that they represent; the second group was not given such explanation.

IV2: **Modularity.** In order to determine how participants reason about contour in different music making strategies, both groups from IV1 were divided as follows: one group was allowed to create music using multiple small blocks that could be linked together to form and manipulate longer sequences; the other group was constrained to use a single large block (details on blocks are in section 4.4).

Combining these, we have four conditions:

C1: no explanation + single block;

C2: explanation + single block;

C3: no explanation + multiple blocks;

C4: explanation + multiple blocks.

4.2 Metrics

4.2.1 Familiarity with Contour

Being familiar with contour means not only being familiar with the association between a musical figure and its metaphorical shape, but also being able to express this association consistently, using an appropriate vocabulary. For this reason, at the beginning of the experimental session, a music analysis exercise was carried out: participants were asked to listen to some melodies and describe them in terms of motion. After this, in order to point participants toward a relation between musical and visual shapes, a picture was presented to them: they were asked to comment on it, and then they were instructed to use the tabletop interface to make music that could relate to the picture. After the music making task, the music analysis task was then repeated, using the same melodies, in order to evaluate if and how the participants changed their descriptions of musical movement, that is, if and how performing the music making task had any effect on their ability to describe music.

4.2.2 Stress, Enjoyment, Concentration

A major part of the study was to investigate the effects of a stress-free instrument on participants' enjoyment and their capacity to make music. It is arguably difficult to measure stress, enjoyment, and concentration. A range of techniques can be employed, for example physiological indicators such as heart rate and skin conductance, or observing a state of flow [14, 15], or even asking participants to report on their experience. However, such techniques may create discomfort to participants, or be affected by observation and self-assessment bias.

This study adopted a mixed approach in which participants' self-assessment was evaluated in conjunction with the researcher's observations and field notes – including for example notes about gesturing, body position, non-verbal expressions, and so on. In this way, participants were not subject to undue stress, and biased reports could be mitigated.

4.3 Participants

Participation in this study was voluntary, anonymous, and involved only one participant per session. Participants were persons willing to improve their music appreciation skills, or even to begin to study music. Since the study involved people acquiring the notion of contour, the ideal participants would have no musical background, so that we could assume their unfamiliarity with contour. However, obtaining a reasonably sized sample composed of people meeting these criteria proved difficult; therefore participants were sampled from the general population, and their background skills were assessed individually to put their answers in context. For example, a skilled musician could be already aware of contour and proficient in using the concept, whereas a person lacking musical training would probably not be.

Participants were not told about the purpose of the study, as we were investigating whether and how they acquired a notion that they were assumed not to be familiar with before. This also means that each participant could only take part in the study once.

4.4 Software

A tabletop application was developed specifically for this study. While it is true that many musical tabletop applications already exist, very few of them present the specialised kind of affordances that this study required. Although developing bespoke software can be costly in terms of time and expertise, the context in which the development happens, academic research, allows the developers to closely monitor the system at all stages and fix problems as they appear. Some other benefits are:

- bespoke software can be tailored to a **specific research question**, and can limit unrelated features that might appear in third-party applications;
- the **user interface** can be kept minimal, meaning a system that can be learned quickly, and is suitable for short experimental sessions;
- the software can be made as friendly and simple as desired to accommodate **different experience levels** and **different types of users**;
- deep and **detailed time stamped logging** can be implemented, which gives precise data to complement qualitative data such as audio/video recordings, worksheets, and interviews.

A screenshot of the interface that was developed for this study is shown in figure 1. Short musical phrases are represented by the grids shown in the picture. These are blocks – which we call *modules* – that can be connected and rearranged to produce longer melodies. The horizontal axis of each block represents time, and the vertical axis represents pitch. Figure 1 shows four connected blocks with time divided in eight segments and five different pitches. If we

interpret a block as a 4/4 bar divided in eighths with pitches chosen from a C major pentatonic scale, a possible interpretation of the configuration above could be as in figure 2

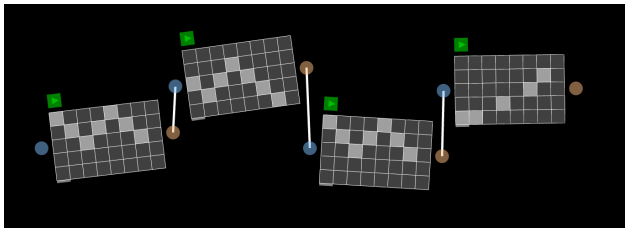

Figure 1: The software in "multiple blocks" mode

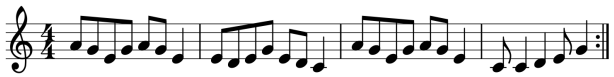

Figure 2: A possible interpretation of figure 1

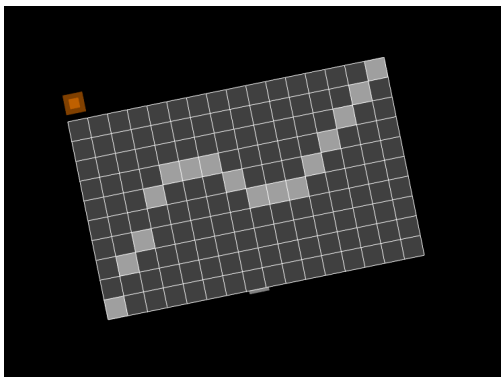

Figure 3: The software in "single block" mode

Any kind of configuration can be implemented. During the study, two configurations were used:

- conditions C1 and C2 offered a single board with time subdivided into 32 parts, using a F suspended pentatonic scale (F, G, A♯, C, D♯) spanning over four octaves plus one note, hence 21 pitches in total;
- conditions C3 and C4 offered multiple blocks with time subdivided into 16 parts, using the same scale as conditions C1 and C2, spanning over two octaves plus one note, hence 11 pitches in total.

A pentatonic scale was chosen because it allowed beginners to compose arbitrarily long melodies on a single chord.

The application was designed around the concept of contour with the purpose of making the relationship between pitch movement and visual shapes explicit. The grid design is inspired by the piano roll editing mode used in many MIDI sequencers; therefore the design was already known to be functional, and it was also easy to use with a gestural interface such as a touch-sensitive digital tabletop.

The conditions relating to melody length also affected the appearance of the blocks and the behaviour of the Play/Stop button that every block features at the top-left corner.

- In the **single block** conditions C1 and C2, only one block was presented to the user, and no more could be added to the workspace. Tapping the Play button would turn it into a Stop button and would start playback of the block in a loop.
- In the **multiple blocks** conditions C3 and C4, left and right handles were provided for the user to link the blocks with each other to create longer melodies – or sequences. In this case, when the Play button was tapped, the corresponding block would start to play, and the playhead would move through all the blocks, playing the sequence in a loop.

4.5 Protocol

This section describes the experimental protocol summarised in figure 5.

4.5.1 Demographics

At the beginning of the session, demographic data was collected, such as whether and how participants had studied music, whether they had ever played a musical instrument, whether they had ever tried to make original music, and how confident they were in their ability to do so. As explained in section 4.3, having participants sampled from the general population means that they were not necessarily musically inexperienced, therefore their answers and performance in the experimental sessions might have been influenced by this. For this reason, demographics were used to inform the analysis of the worksheets relating to the music and picture analysis tasks, as well as the music making task, which are described in the following sections.

4.5.2 Music analysis

The first part of the experimental session was an exercise in analysis composed of two sub-tasks.

In the first sub-task, participants were asked to listen to three melodies, excerpts from "Twinkle twinkle little star", "Frère Jacques", and "Morning has broken". Participants were asked to complete a worksheet in which they had to say how many sections they would divide the melodies into, and to describe the movement of each section. The somewhat vague term "movement" was used deliberately to encourage participants to use their own interpretation. The use of more specific terms such as "rise and fall" might have been leading as to what they were expected to say, therefore making their answers less valid in light of hypothesis 1. Participants were allowed to listen to the melodies as many times as they wished, and they were also encouraged to describe movement in their own words. No further guidance was provided during this task.

4.5.3 Picture analysis

The task of making music can be daunting, especially for people with little musical knowledge. A skilled musician may have no difficulty in creating music out of thin air, but since this study primarily addressed persons with potentially no musical training, giving them a starting point may make the task easier to approach.

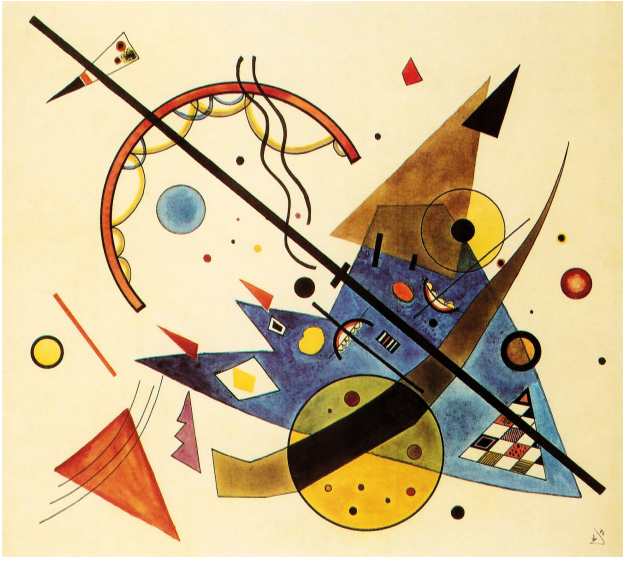

Figure 4: Wassily Kandinsky, *Arch and Point*, 1923.

In the second sub-task, participants were asked to comment on a painting in their own terms and according to their own intuition, and to write their comments on a worksheet. The painting (figure 4) was chosen to clearly present certain geometric features that could be related to figures in contour. The reason for this was that, during the course of the experimental session, the participants would be asked to compose a melody according to their interpretation of the picture. Some form of guidance was provided in the worksheet, inspired by a typical GCSE artwork analysis worksheet [16], in order to make sure that participants would give relevant information.

4.5.4 Introduction to contour

After the analysis phase and before the composition phase, two things could happen, according to which condition the participants were assigned to: either the participants were given a brief introduction to contour, or they were not. If the former was the case, participants were given a brief explanation of what contour is and how it works: pre-recorded short musical snippets were played, such as ascending and descending ramps, upward and downward arcs, and so on; for each snippet, a sketch of its contour was drawn on a whiteboard, and also described in terms of visually similar concrete objects, such as stairways (for ramps), bridges (for arcs), pendula and sea waves (for undulations, repetitions), and so on. The whiteboard was left visible to the participants as a reference during the music making task.

4.5.5 Music making task

In this phase, participants were asked to use the DTMI to compose a melody that could describe the picture according to their interpretation. The DTMI was configured according to the assigned experimental condition.

4.5.6 Reflection and debriefing

The purpose of this phase was to allow participants to reflect on their work in light of the tasks they had just carried out.

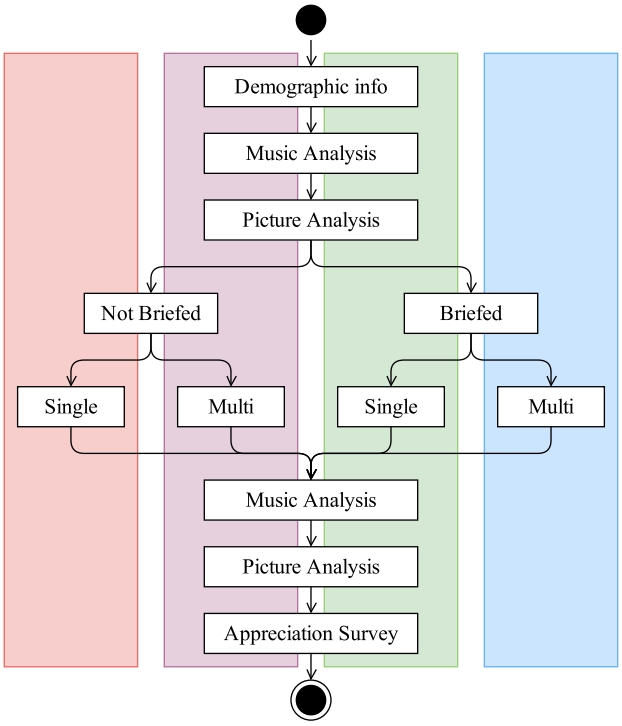

Figure 5: The activities that participants go through depending on which condition they are in.

The analysis tasks were repeated by asking participants to fill in the same worksheets again using the same musical and visual materials as before. This led to an informal discussion about the session, and the participants' impressions and remarks were recorded.

Finally, participants were handed an appreciation questionnaire, relating to hypothesis 2, in order to assess their experience in the study. This questionnaire inquired about the perceived difficulty of accomplishing the music making task, whether and how much participants enjoyed the experience and concentrated on the task, whether they were now more or less confident in their ability to make original music, and whether they thought they would attempt such activity in the future.

4.5.7 Data collection

Questionnaires included participants' demographic information, such as whether and how they had studied music, whether they had ever played a musical instrument, and whether they had ever tried to make original music and how confident they were in their ability to do so. These data were collected to inform the analysis of the worksheets and the music making task.

In the first part of the study, participants were asked to complete two analysis tasks using the worksheets provided to record their answers. As detailed in section 4.5.2, this part was repeated after the music making task.

During the music making task, the application described in section 4.4 recorded events such as touches, strokes, gestures, and so on. To gather a more complete understanding of the interaction with the system, participants were also video recorded.

Q1a		Q2a		Q4a	
Never	4	No	7	Never	13
Informally	3	One	8	Once or twice	6
Formally	13	More	5	More	1

Table 1: Q1a: "Have you ever studied music?"; Q2a: "Do you play a musical instrument?"; Q4a "Have you ever composed original music?"

	Q1b mean	Q2b w. mean	Q4b w. mean
C1	11.67	2.75	1.60
C2	5.67	1.00	1.00
C3	3.33	2.67	1.60
C4	15.20	1.67	1.60
all	9.86	2.17	1.47

Table 2: Q1b: "If you have studied music, for how many years?"; Q2b: "If you play a musical instrument, how well do you think you do?"; Q4b: "How confident are you in you ability to compose original music?"

Finally, participants were handed an appreciation questionnaire at the end of the session in order to assess their experience in the study. In particular, this questionnaire inquired about the perceived difficulty of accomplishing the music making task, whether and how much participants enjoyed the experience and concentrated on the task, whether they were more or less confident in their ability to make original music, and whether they think they would attempt such activity in the future.

5. RESULTS AND DISCUSSION

Twenty participants volunteered for the study, coming from staff available on the University's campus, and they were randomly assigned to the four conditions, with the only constraint that they had to be as evenly distributed as possible. This resulted in five participants per condition.

5.1 Analysis

5.1.1 Demographics

The aim of the study was to explore the possible role of interactive tabletops in helping people to discuss and to reason about music; the demographic data are summarised in table 1, and were used as background to the analysis of the worksheets and the music making task. The distribution of answers to questions 1 and 2 was quite skewed toward participants that received formal music education, and a better distribution could have been achieved by examining the demographic data before assigning the condition.

Question 4, related to hypothesis 2, inquires about whether participants have ever tried making original music and how confident they were in their ability to do so on a 1-5 scale

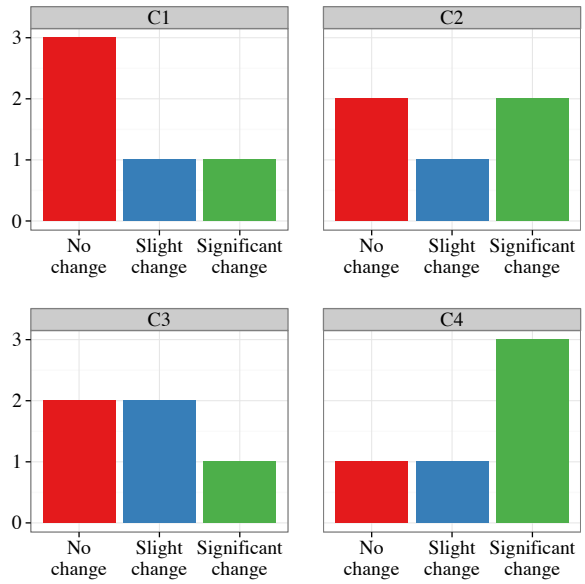

Figure 6: Changes in music description per condition

terms	count
ascending, up(ward), rising, climbing	26
descending, down(ward), falling	26
arc, up and down	10
wave, undulation	9

Table 3: Terms used to describe movement across conditions by all participants, including before and after the music making task

(table 2). Most participants, 19 out of 20, reported having never, or very seldom, tried to make original music, and self-reported confidence across all conditions was quite low on average. This is positive since it makes it possible to assess how effective the interface is in assisting participants with little musical experience and confidence to create, and reason about, music.

Question 3 asked the age at which participants started studying music, if they had. However, this question was marked as optional, due to its sensitive nature, and very few participants answered, therefore we decided to ignore it in our analysis.

5.1.2 Music Analysis Exercise

The purpose of this exercise relates to hypothesis 1: to evaluate if, and to what extent, taking part in the study would affect participants' understanding of contour and its vocabulary. Despite the vague term "movement" used in the worksheet, few participants asked for clarification, while most of them went by their own interpretation, as they were explicitly asked to do. A slightly less vague explanation was given to those who requested it, but it was still kept deliberately vague in order to not influence the answers.

All participants, in the first iteration of the exercise, showed an intuitive association between time and left-right move-

	w. mean	w. sd
C1	1.60	1.07
C2	2.40	1.07
C3	1.20	0.71
C4	2.20	1.37
all	1.85	1.20

(a) The music making task was difficult

	w. mean	w. sd
C1	4.00	0.85
C2	4.00	0.00
C3	4.20	1.56
C4	4.40	0.71
all	4.15	0.98

(b) I enjoyed making music

	w. mean	w. sd
C1	4.00	0.85
C2	3.80	1.31
C3	4.20	0.71
C4	4.40	0.71
all	4.10	0.98

(c) I concentrated on the task

	w. mean	w. sd
C1	1.80	0.94
C2	1.60	1.07
C3	2.20	1.84
C4	2.40	1.76
all	2.00	1.49

(d) I am confident in my ability to make original music

	w. mean	w. sd
C1	2.60	1.60
C2	2.40	2.33
C3	2.60	1.60
C4	2.20	2.14
all	2.45	1.79

(e) I think that I will make original music in the future

Table 4: Q5: Appreciation survey (all answers on a 1-5 scale)

ment, possibly due to cultural influence as most of them were primarily educated in a Western way; they also intuitively related pitch changes and up-down movement, for example by using words such as “up”, “down”, “rising”, and “falling”. Some of the participants that used contour-related terminology even sketched rather precise contour shapes to clarify their understanding. It is worth noting that, at this point, participants in conditions C2 and C4, the ones that included an explicit explanation of contour, were not yet given the explanation.

Figure 6 shows to what extent answers to this exercise changed in the second iteration, that is after the music making study, and after the explanation of contour in conditions C2 and C4. We identified a “slight” change when participants confirmed the sectioning of the melodies and changed their answers for up to two sections toward a clearer and more precise description in terms of contour features; we identified a “significant” change when participants changed the sectioning of the melodies, and/or changed their descriptions of contour for more than two sections toward a clearer and more precise description, and in particular if using an appropriate vocabulary.

It is clear that, on average, more significant changes happened for conditions C2 and C4, as it was reasonable to expect as an effect of explaining contour explicitly to them as part of the experimental session. However, it is also interesting to look at how participants changed their descriptions after the music making task.

Participants in conditions C1 and C3, after performing the music making task, had a generally clearer idea of what they were hearing, although most of them still used inconsistent descriptions like they did in the first iteration – i.e. using terms such as “progress”, “echo”, “choice”, “reply” – and, in some cases, the quality of their descriptions in the second iteration related less to contour and more to other qualities of melody, such as speed, pace, rhythm, and so on.

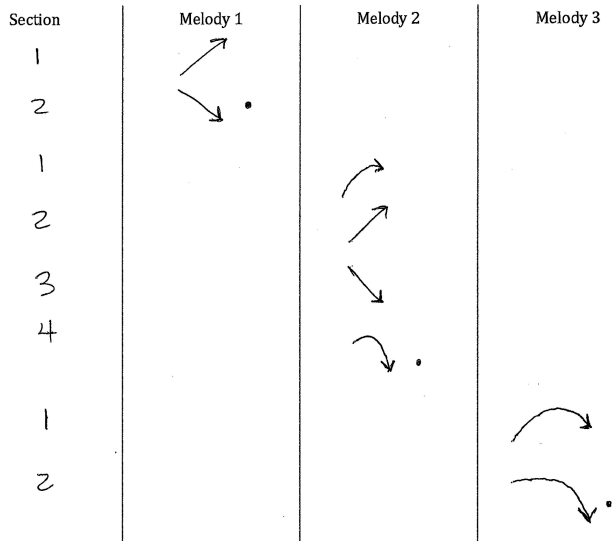

Figure 7: Sketches drawn by a participant in condition C2 for the second iteration of the music analysis exercise.

On the other hand, the few participants in this group that also reported higher levels of music education showed less significant change in their descriptions, and also used an appropriate vocabulary – using terms such as “up/down”, “climbing”, and “descending” – the first time they performed the exercise. Table 3 summarises the most frequently used exact terms used by participants across conditions considering both before and after worksheets.

Participants in conditions C2 and C4 initially gave comparable answers to those in conditions C1 and C3. However, in the second iteration of the exercise – i.e. after contour was explained and after they performed the music making task – participants in conditions C2 were able to better identify and describe the melodies – using words that were used

to explain contour, such as "ramp" (3 participants), "undulation" (2 participants), "arc" (2 participants) – and even using sketches if they did not use them before (figure 7), as sketches were part of the materials used to explain contour.

To summarise, answers changed across all four conditions in 12 out of 20 cases, as shown in figure 6. Participants that were given an explanation of contour demonstrated having understood that contour has a specific vocabulary, and could use it consistently with the explanation. This means two things: first, the music making interface has the potential to help people to intuitively realise that there is a connection between music and its contour shapes; second, when the concept of contour was made explicit by explaining it, people were more likely to use a specific vocabulary and were confident in using it. Therefore tutoring plays an important role in the process, a result that is confirmed by the literature [17].

5.1.3 Music Making Task

Most participants spent around 10-15 minutes working on the system, although a few spent just about 2-3 minutes and one spent over 30 minutes. Also, 19 out of 20 participants, composed several different melodies before ending the session, either by making progressive changes or by repeatedly starting from scratch. Participants in conditions C1 and C2, those who were allowed to use only one block, spent most of their time making changes, often major ones, to their work before being satisfied and ending the session.

During informal discussions right after the music making tasks, participants explained how they tried to relate the music they made to various aspects of the picture. For example, most of them said that they tried to replicate some of the shapes that they saw in the picture, while some of them disregarded the shapes and instead preferred to go by their feelings for the picture – i.e. most of the participants that related the picture to outer space and science fiction said that they tried to create an eerie feeling, reminiscent of science fiction movie soundtracks from the '50s and the '60s, while most of the participants that associated the picture with order, geometry, and mathematics, said that they tried to create music with short, repeating, and clearly identifiable patterns, such as short ramps or small arcs sometimes composed of as little as three notes and repeated several times. It is also interesting to note that, although the software was designed to be strictly monophonic, two participants, both in condition C3, chose to use two parallel chains of three modules each, effectively implementing polyphony. They both felt that in that way they were able to better express what they felt the picture represented – i.e. "chaos", "superimposition", "convergence".

To summarise, all participants – regardless of their ability to discuss contour exhibited in the worksheets – could relate visual shapes to musical shapes after the music making task. Video analysis shows participants often looking at the picture, imitating its shapes by gesturing mid-air, and reproducing these gestures by drawing on the tabletop. Video analysis also confirms that participants were hardly ever surprised by how the system translated their gestures into music, seamlessly applying corrections where they felt the system made a mistake, and moving on with their work. Data logging shows a preference for simple shapes – straight lines, arcs, undulations – that progress from left to right – or right to left, in a few cases – rather than repeatedly going back and forth from one side to the other.

	before	**after**	**difference**
C1	1.60	1.80	0.20
C2	1.00	1.60	0.60
C3	1.60	2.20	0.60
C4	1.60	2.40	0.80
all	1.47	2.00	0.53

Table 5: Comparison of confidence before (table 2) and after (table 4d))

5.1.4 Stress and Engagement

Table 4 summarises the the participants' self-assessment regarding their experience in the study.

Questions 5a through 5c suggest that participants found the task sufficiently easy and enjoyable, which allowed them to concentrate more on making music rather than on figuring how the system worked. It is important to note that, in answering question 5a, some participants took "music making task" to mean both using the interface and the music making task itself; therefore, answers to question 5a do not reliably explain whether participants found it easy or difficult to just use the tabletop interface, or to just describe the picture with music, or even these two combined.

Question 5d measures how confident participants were in their ability to make original music after taking part in the study. Table 5 shows the difference in self-confidence from before to after the music making task. While participants in all conditions reported an increase in self-confidence, it is interesting to note that participants in conditions C2 and C4 – i.e. conditions where an explanation of contour was given – reported a larger increase on average. By analysing individual cases, one participant in condition C4 reported an increase of 2 points, whereas participants in conditions C1 and C3 reported a maximum increase of 1 point, and one of them even reported a decrease.

Answers to question 5e are also interesting: individually, participants that reported lower confidence in their ability to make original music before the session were likely to consider trying to make original music again after the session; on the other hand, participants who were already confident felt that they were not more likely to make original music in the future than they were before.

Questions 5d and 5e together tell us an important result, confirming our hypothesis 2. The system has certainly a potential as a learning tool, but as a tool it can only do part of the work: figure 6 suggests that tutoring is still important to acquire self-confidence, a fundamental factor for learners, and particularly for training musicians, as shown by previous findings in the literature [17].

6. CONCLUSION

This study was designed to gather an initial insight on whether DTMIs can be useful to help people acquire a simple musical concept and to use it to create and discuss music – in this case, melodic contour – while providing an engaging experience. The analysis suggests that the answer tends towards "they can", but it also highlights the importance of tutoring. Technology can make certain aspects of music making easier – in this case, it allows people who cannot play a traditional instrument to make music with limited effort – and it can provide an implicit understanding of certain concepts – as the results under conditions C1 and C3 suggest. However, the results from conditions C2 and C4 clearly show that an explicit explanation of contour helped participants to understand it and use it confidently and consistently to express their intention. Finally, we found that an appropriately designed DTMI can provide an enjoyable way of making music, even for people with no musical background – although it should be noted that most of our participants had some musical experience, however limited. In particular, we found that it can increase self-confidence in one's ability to explore and make music – an important first step toward engaging in music and learning more about it – and even more so when tutoring is provided – as results from conditions C2 and C4 show – which confirms previous findings [17].

7. REFERENCES

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